

## CONTINUOUS PROCESSES FOR PREPARING CONCENTRATED AQUEOUS LIQUID BIOCIDAL COMPOSITIONS

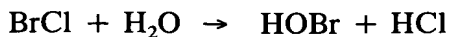
### REFERENCE TO RELATED APPLICATIONS

*See also*  
This is a continuation-in-part of commonly-owned copending Application No. ~~[Case SU-7073-C]~~, filed November 17, 1999, which in turn is a continuation-in-part of commonly-owned copending Continued Prosecution Application (CPA) No. 09/088,300, which continues the prosecution of prior commonly-owned copending Application No. 09/088,300, filed June 1, 1998.

### BACKGROUND

Bromine-based biocides have proven biocidal advantages over chlorination-dechlorination for the microbiological control of cooling waters and disinfection of waste treatment systems. The water treatment industry recognizes these advantages to be cost-effective control at higher pH values, almost no loss in biocidal activity in the presence of ammonia, and effective control of bacteria, algae and mollusks.

A common way of introducing bromine based biocides into a water system is through the use of aqueous NaBr in conjunction with NaOCl bleach. The user feeds both materials to a common point whereupon the NaOCl oxidizes the bromide ion to HOBr/OBr<sup>-</sup>. This activated solution is then introduced directly into the water system to be treated. The feeding of the two liquids in this fashion is necessary because the HOBr/OBr<sup>-</sup> mixture is unstable and has to be generated on-site just prior to its introduction to the water. Furthermore, the feeding, and metering of two liquids is cumbersome, especially as the system has to be designed to allow time for the activation of bromide ion to occur. Consequently many biocide users have expressed the need for a single-feed, bromine-based biocide. Molecular bromine chloride is deemed to meet these demands. It is a liquid at room temperature and can be fed directly to the water system, where immediate hydrolysis occurs to yield HOBr.



Bromine chloride is a fuming, red liquid or gas, with a boiling point of 5°C, and a vapor pressure of 1800 mm at 25°C. It corrodes most metals in the presence of water.

5 It can be seen that certain characteristics of bromine chloride -- especially its corrosiveness, high vapor pressure and fuming tendencies -- necessitate care and skill in its handling and use.

10 An economically acceptable way of stabilizing high concentrations of aqueous solutions of bromine chloride is described in U.S. Pat. No. 5,141,652 to Moore, et al. The solution is prepared from bromine chloride, water and a halide salt or hydrohalic acid. These solutions were found to decompose at a rate of less than 30% per year and in cases of high halide salt concentration, less than 5% per year. Moreover, solutions containing the equivalent of 15% elemental bromine could be prepared. Unfortunately, the relatively high acidity of these solutions and their tendency to be corrosive and fuming impose limitations on their commercial acceptance.

15 The commonly-owned copending continued prosecution application referred to at the outset describes, *inter alia*, a new process of forming concentrated aqueous solutions of biocidally active bromine and in so doing, provides novel and eminently useful concentrated aqueous biocidal solutions of bromine chloride. Such solutions are formed by a process which comprises mixing (a) bromine chloride with (b) an aqueous solution of alkali metal salt of sulfamic acid (preferably the sodium salt), the resulting solution having a pH of at least about 7, *e.g.*, in the range of 7 to about 14, and preferably above 7 to about 14. Most preferably the pH is in the range of about 13.0 to about 13.7. The amounts of (a) and (b) used are such that (i) the content of active bromine in the solution is at least 100,000 ppm (wt/wt) and (ii) the atom ratio of nitrogen to active bromine from (a) and (b) is greater than 0.93, and preferably is greater than 1.

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The commonly-owned copending application referred to at the outset of which the present application is a continuation-in-part describes, *inter alia*, a process of producing a concentrated liquid biocide composition by a process which comprises (A) continuously feeding into mixing apparatus (i) bromine chloride and (ii) an aqueous solution of alkali metal salt of sulfamic acid (preferably a sodium salt of sulfamic acid), proportioned to produce an aqueous product having an active bromine content of at least 100,000 ppm (wt/wt), and an atom ratio of nitrogen to active bromine from (i) and (ii) greater than 0.93 (preferably greater than 1), and (B) withdrawing such product from the mixing apparatus at a rate sufficient to enable the continuous feeding in A) to be maintained. In certain embodiments of the process, the bromine chloride is continuously formed from equimolar amounts of bromine and chlorine, and at least a portion of the bromine chloride being continuously produced is used as the continuous feed of bromine chloride in step A) above. Thus in plant facilities where bromine chloride is required or desired for use(s) in addition to that required to maintain the continuous feed of (i) in step A) above, the continuous production of the bromine chloride can be scaled up to serve all such uses. A preferred embodiment of the process includes, in addition to steps A) and B) as described above, the following concurrent operation, namely, continuously, but alternately, withdrawing from at least one and then from at least one other of at least two reaction vessels, an aqueous solution of alkali metal salt of sulfamic acid at a rate that maintains the stream of (ii) in A), and during the time the solution is being withdrawn from said at least one of at least two reaction vessels, forming additional aqueous solution of alkali metal salt of sulfamic acid in at least one other of at least two reaction vessels from which solution is not then being withdrawn. In this way, aqueous alkali metal sulfamate solution can be continuously withdrawn from one or more tanks ("Tank(s) I") to serve as the continuous feed of (ii) in A), while forming more of such solution in one or more other tanks ("Tank(s) II"), so that when Tank(s) I is/are depleted, the system is switched to Tank(s) II which then serve(s) as the supply for the continuous feed of (ii) in A) until depleted, and by that time more of such solution has been formed in Tank(s) I. Thus by alternating the supply and the production from one tank (or group of tanks) to another tank (or group of tanks) and switching back

and forth between the filled tanks as the supply, the continuous feed of the aqueous alkali metal sulfamate solution can be maintained without material interruption.

### SUMMARY OF THE INVENTION

One objective of this invention is to enable a process of the last-mentioned commonly-owned copending application wherein at least a portion of the bromine chloride is being continuously produced and used as one of the continuous feeds, to be carried out not only in a commercially-feasible, highly efficient manner on a continuous basis, but in addition, to include efficient automatic continuous process control in such process. Other objectives may appear hereinafter.

In one of its embodiments this invention provides a process of producing a concentrated liquid biocide composition which process comprises:

- a) continuously forming bromine chloride from separate feed streams of bromine and chlorine by maintaining said streams under automatic feed rate control whereby the streams are continuously proportioned to come together in equimolar amounts to form bromine chloride;
- b) continuously forming an aqueous product having an active bromine content of at least 100,000 ppm (wt/wt), a pH of at least 7, and an atom ratio of nitrogen to active bromine greater than 0.93:1 by feeding into mixing apparatus separate feed streams of (i) bromine chloride formed in a) and (ii) an aqueous solution of alkali metal salt of sulfamic acid, under automatic feed rate control whereby the feed streams are continuously proportioned to come together in amounts that produce an aqueous product having an active bromine content of at least 100,000 ppm (wt/wt), a pH of at least 7, and an atom ratio of nitrogen to active bromine from (i) and (ii) greater than 0.93:1; and
- c) withdrawing said aqueous product from said mixing apparatus at a rate sufficient to enable the continuous feeding in a) and b) to be maintained.

Preferably the automatic feed rate controls in a) and b) are under nested cascade ratio flow control.

5 Since the reaction between the bromine chloride and the alkali metal sulfamate solution is exothermic, it is desirable to control the temperature of this reaction so that the temperature of the aqueous product being formed does not exceed about 50°C, and preferably is in the range of about 25 to about 40°C, and most preferably is maintained at about 30°C. Such control may be accomplished, for example, by promptly passing the effluent from the mixing apparatus through a proximately-disposed heat exchanger to remove excess heat from the effluent. Another way of accomplishing such temperature control is to suitably precool the aqueous alkali metal sulfamate solution before it reaches the mixing device such that the temperature of the effluent stays within the foregoing temperature conditions. Both such methods of temperature control can be utilized, if desired.

10 Another embodiment of the above process includes, in addition to steps a), b), and c) as described above, forming, either periodically or continuously, the aqueous alkali metal sulfamate solution by reaction between sulfamic acid and alkali metal base such as alkali metal hydroxide in water.

15 One preferred embodiment of the above processes includes the following concurrent operation, namely, continuously, but alternately, withdrawing from at least one and then from at least one other of at least two reaction vessels, an aqueous solution of alkali metal salt of sulfamic acid at a rate that maintains the stream of (ii) in b), and during the time the solution is being withdrawn from at least one of at least two such reaction vessels, forming additional aqueous solution of alkali metal salt of sulfamic acid in at least one other of such reaction vessels from which solution is not then being withdrawn. In this way, aqueous alkali metal sulfamate solution can be continuously withdrawn from one or more tanks ("Tank(s) I") to serve as the continuous feed of (ii) in b), while forming more of such solution in one or more other tanks ("Tank(s) II"), so that when Tank(s) I is/are depleted,

the system is switched to Tank(s) II which then serve(s) as the supply for the continuous feed of (ii) in A) until depleted, and by that time more of such solution has been formed in Tank(s) I. Thus by alternating the supply and the production from one tank (or group of tanks) to another tank (or group of tanks) and switching back and forth between the filled tanks as the supply, the continuous feed of the aqueous alkali metal sulfamate solution can be maintained without material interruption.

Another preferred embodiment of the above processes includes the following concurrent operation, namely, continuously withdrawing an aqueous solution of alkali metal salt of sulfamic acid from a circulating inventory of alkali metal salt of sulfamic acid, the withdrawal being at a rate that maintains the stream of (ii) in b), and continuously replenishing the circulating inventory from a supply of such aqueous solution of alkali metal salt of sulfamic acid from a reaction vessel in which aqueous solution of alkali metal salt of sulfamic acid is produced at least periodically in quantity sufficient to at least maintain such circulating inventory. By maintaining a circulating inventory of the aqueous solution of alkali metal salt of sulfamic acid in a pump around circulation loop, only one reaction vessel is required for forming such solution from sulfamic acid, an alkali metal base such as alkali metal hydroxide, and water.

The above and other embodiments and features of this invention will be still further apparent from the ensuing description, the accompanying drawings, and/or the appended claims.

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic flow diagram of a plant layout suitable for the practice of a continuous processes.

Fig. 2 is a schematic flow diagram of a plant layout of this invention in which an automatic flow control system is included.

Fig. 3 is a schematic flow diagram of another plant layout of this invention in which an automatic flow control system is included.

### FURTHER DETAILED DESCRIPTION OF THE INVENTION

Various types of mixing apparatus can be used in the practice of this invention. In one preferred embodiment the mixing apparatus comprises a static mixer. The static mixer can be of any suitable design and configuration as long as it is capable of continuously receiving the continuous feed streams of bromine chloride and aqueous alkali metal sulfamate solution, and continuously discharging a mixture formed from these feed streams that is substantially uniform in composition and thus satisfies product specifications.

Another preferred mixing apparatus comprises a vessel equipped with a mechanical stirrer. In this case, the vessel continuously receives the continuous feed streams of bromine chloride and aqueous alkali metal sulfamate solution, and either continuously or intermittently discharges a substantially uniform mixture formed from these feed streams. The mechanical stirrer can be programmed to operate continuously or intermittently as long as the discharge from the vessel is constantly substantially uniform in composition. Thus if the discharge from the vessel is intermittent, the incoming continuous feeds are preferably agitated during at least most of the time the vessel is filling up to a predetermined volume at which point the contents of the vessel are discharged more rapidly than the total incoming feeds until the vessel reaches a predetermined low volume, at which point the discharge is discontinued so that the vessel begins to fill up again. On the other hand, if the discharge is continuous, the system is designed and constructed such that the total incoming volume to the vessel and the concurrent outgoing volume from the vessel remain equal and so that the vessel continuously contains a predetermined volume of contents which are being mixed by the mechanical stirrer. In such case, the stirrer preferably is operated continuously.

The bromine chloride can be preformed bromine chloride maintained and sourced from storage tanks. Preferably however the bromine chloride is concurrently being prepared in a suitable corrosion-resistant reaction vessel on a continuous basis from

equimolar amounts of bromine and chlorine. As indicated above, the amount of bromine chloride being continuously produced can equal the amount of bromine chloride being continuously fed to the mixing apparatus, when there is no other need or desire for additional amounts of bromine chloride. But if there are other such needs or desires, the amount of bromine chloride production can be scaled up to meet such needs or desires. The bromine chloride is typically formed by contacting the reactants in equimolar quantities and maintaining the temperature of the mixture in the range of about 10 to about 50° C.

Use of bromine chloride as the source of the active bromine in the concentrated stabilized liquid biocide formulations produced pursuant to this invention is highly advantageous. When such biocidal formulations are used to treat water, all of the bromine of the bromine chloride is made available as active bromine in the resulting highly dilute solution. In other words, the chlorine of the bromine chloride is converted in the process to dissolved alkali metal chloride salt, thereby liberating the bromine as the active bromine content of the biocidal composition. Thus the more expensive component of the bromine chloride -- viz., bromine -- is fully utilized in forming active bromine in the aqueous biocidal composition, and concurrently the less expensive component -- the anionic chlorine in the bromine chloride -- makes this beneficial result possible.

The aqueous solution of alkali metal salt of sulfamic acid (alkali metal sulfamate) can be preformed and sourced from storage vessels in supplying the other continuous feed to the mixing apparatus. However it is preferred to concurrently produce such aqueous solution at a rate sufficient to at least continuously supply the amount required to maintain such continuous feed to the mixing apparatus. If there are other needs or desires for such aqueous solution, the amount of solution produced can be scaled up to satisfy such needs or desires.

It is possible to form the aqueous solution of alkali metal salt of sulfamic acid by mixing dry sulfamic acid with a dry water-soluble the alkali metal base also in the dry state, and then mix the resultant dry mixture of solids with water. It is also possible to form the



aqueous solution of alkali metal salt of sulfamic acid by mixing dry sulfamic acid with an aqueous solution of alkali metal base. However, the aqueous solution of alkali metal sulfamate is preferably formed by mixing together a slurry of sulfamic acid in water and a solution of the water-soluble alkali metal base.

5 Any water-soluble inorganic alkali metal base can be used in forming the aqueous solution of alkali metal sulfamate. Examples of such bases include the oxides, hydroxides, carbonates, bicarbonates, acetates, sulfates, and the like. While a water-soluble basic salt or oxide of any alkali metal can be used, the sodium salts or oxides are preferred. However potassium salts or oxides are also very useful. Mixtures of two or more  
10 water-soluble sodium bases, mixtures of two or more water-soluble potassium bases, or mixtures of one or more water-soluble sodium bases and one or more water-soluble potassium bases can be used. Highly preferred are aqueous sodium hydroxide solutions which can be formed from sodium oxide or sodium hydroxide. Typically the aqueous solution will contain in the range of about 10 to about 55 wt% of the alkali metal base, but any concentration of such base that enables the formation of an aqueous bromine  
15 chloride solution meeting the pH requirements of this invention can be employed.

Besides having an active bromine content of at least 100,000 ppm (wt/wt), the concentrated ~~aqueous alkali metal sulfamate~~ solution emanating from the mixing apparatus preferably has a pH of at least 7, *e.g.*, a pH in the range of 7 to about 14, and preferably  
20 above 7 to about 14. Most preferably this solution is <sup>a</sup>~~an overbased alkali metal sulfamate~~ solution with a pH in the range of about 13.0 to about 13.7. The pH of the concentrated <sup>solution</sup> is typically governed by the pH of the aqueous alkali metal sulfamate solution used as the feed to the mixing apparatus.

25 It is possible for the solution emanating from the mixing apparatus to have a pH with a numerical value lower than desired, and to feed additional base into the solution after it has left the mixing apparatus to raise the pH to the desired numerical value. Alternatively, a separate aqueous solution of alkali metal base can be fed concurrently and

continuously to the mixing apparatus to achieve a more alkaline (basic) concentrated product solution leaving the mixing apparatus. Neither of these latter two procedures is a preferred way to operate, however.

5 Therefore, in the preferred operating modes the proportions of the bromine chloride and the aqueous alkali metal sulfamate solution continuous feed streams to the mixing apparatus are such that (i) the content of active bromine in the resulting product solution is at least 100,000 ppm (wt/wt) and (ii) the atom ratio of nitrogen to active bromine from these feed streams is greater than 0.93, and more preferably in the range of about 1.0 to about 1.4.

10 By utilizing bromine chloride with caustic in the stabilized bromine composition, higher levels of active halogen are achievable, compared to the levels obtained by the addition of sodium hypochlorite to sodium bromide. The process and the compositions formed also have about twice the content of active bromine as the most concentrated solutions produced pursuant to Goodenough, *et al.* U.S. Pat. No. 3,558,503. Moreover, 15 even at the high levels of active bromine that exist in the compositions of this invention, it has been found possible to provide biocidal compositions that maintain these high levels of active bromine for at least a two-month period, and that do not exhibit a visible or offensive vapor or odor during this period.

20 In each of the embodiments of this invention the operation is preferably conducted such that the concentrated product solution produced in the process has an active bromine content in the range of about 120,000 ppm wt/wt (12 wt%) to about 180,000 ppm wt/wt (18 wt%). Also in each of the embodiments of this invention, the atom ratio of nitrogen to active bromine in the concentrated product solution is preferably at least 1:1, *e.g.*, in the range of about 1.1 to about 1.5. Still higher ratios can be employed, if desired. A 25 particularly preferred atom ratio is from 1.0:1 to 1.4:1.

5 The processes of this invention are continuous processes and involve continuous feeds to the mixing apparatus. In addition, some embodiments of the invention involve continuous formation of bromine chloride, or continuous contacting of bromine and chlorine to form bromine chloride, or continuous alternate withdrawal of an aqueous solution of  
10 alkali metal salt of sulfamic acid from at least one reaction vessel while another quantity of such solution is being formed in at least one other such vessel. In such embodiments the term "continuous" or "continuously" is not meant to exclude interrupted feeds or withdrawals. Generally, if such interruptions occur, they are of short duration and are such as not to materially affect the steady state operation of the overall process, and also are  
15 such as not to cause production of a significant quantity of off-specification concentrated product solution. An example of such a slight, non-adverse interruption may occur when switching the flow of aqueous solution of alkali metal salt of sulfamic acid from at least one reaction vessel to another such vessel, an operation which is referred to above as part of a "continuous" feed. As long as such switching operation does not disrupt the operation or result in the formation of a significant quantity of off-specification concentrated product  
20 solution, such interruption is acceptable and is within the spirit of the term "continuous". An exception exists where the term "continuous" does not allow for interruption, namely in any case where both continuous and non-continuous (*e.g.*, "intermittent") operation in a given step or operation are both expressly referred to herein. An example of this exception is the embodiment where product is continuously withdrawn from above-referred-to vessel that is equipped with a mechanical stirrer. Such "continuous" withdrawal is not interrupted because in another embodiment expressly referred to herein, the withdrawal of the same product from the same vessel is specifically described as "intermittent". Thus both alternatives (continuous and non-continuous) are expressly  
25 referred to in this disclosure.

Reference is now made to the drawings, which are largely self-explanatory.

#### Figure 1

In the plant flow diagram schematically depicted in Fig. 1, separate equimolar

streams of bromine and chlorine are fed, preferably continuously, into stirred jacketed reactor 10. The contents <sup>of</sup> reactor 10 are typically maintained at a temperature in the range of about -30 to about 30°C so that bromine chloride is produced, preferably continuously. The bromine chloride is transmitted continuously into mixing apparatus 20. Concurrently sulfamic acid, a 15-25 wt% aqueous solution of sodium hydroxide, and water are charged into either jacketed reactor 30 or jacketed reactor 40, and the resultant mixture therein is agitated and maintained at about 10 to about 50°C. The sulfamic acid and the sodium hydroxide are proportioned to produce in the reactor an aqueous solution of sodium sulfamate having a pH which preferably is in the range of about 13.0 to about 14.0. The reactor 30 or 40 which is not then being used to prepare such aqueous sodium sulfamate solution, contains an identical aqueous solution previously made therein in the same manner. A stream of such aqueous sodium sulfamate solution is continuously withdrawn from reactor 30 or 40 (as the case may be) which contains the previously made solution, and this stream is continuously fed into mixing apparatus 20. The interaction between the bromine chloride and the sodium sulfamate solution tends to be exothermic. Therefore, it is desirable, particularly in large scale facilities, to cool the mixture as it is being formed. The effluent from mixing apparatus 20 is the concentrated stabilized aqueous biocidal formulation. This product solution is transferred from mixing apparatus 20 to a storage tank 50 or equivalent container such as a railcar or tank truck. If mixing apparatus 20 is a static mixer, the effluent from the static mixer is continuously transferred to the storage tank 50. On the other hand, if mixing apparatus 20 is, say, a vessel equipped with a mechanical stirrer, and such vessel is intermittently drained so that its contents oscillate between high and low contents of product solution, the transmission of the product solution from such mixing apparatus 20 to storage tank 50 is intermittent. Means (not shown) such as electrically-operated valves and associated electronics for sensing and signaling when to shut one valve while opening the other are included so that the continuous alternate flow of aqueous sodium sulfamate solution from one and then the other of reactors 30 and 40 to mixing apparatus 20 can be maintained on a continuous basis.

Instead of the separate feeds depicted in the drawing of sulfamic acid, a 15-25 wt% aqueous solution of sodium hydroxide, and water that alternate back and forth between one of reactors 30 and 40 while the other reactor is being drained, separate flows of the aqueous solution of sodium hydroxide and a preformed aqueous slurry of sulfamic acid can be fed alternately to these reactors. It may be expected that other variations and details in the depicted schematic plant flow diagram and/or in the mode of operation will now be readily apparent to those of ordinary skill in the art.

#### Automatic Process Flow Controls

In the practice of this invention, the various process embodiments are carried out with automatic process flow controls now to be described. Exemplary flow diagrams involving such automatic process flow controls are schematically depicted in Figs. 2 and 3. Both such flow diagrams utilize the same method to simultaneously feed bromine, chlorine, and sodium sulfamate. The difference between the two is that Fig. 2 requires two vessels. The first vessel is used to neutralize sulfamic acid to sodium sulfamate. The second vessel is used as a feed tank to continuously feed sodium sulfamate to the rest of the process. The flow diagram of Fig. 3 is a "1-pot" process using a single reactor vessel to continuously neutralize sulfamic acid and feed sodium sulfamate to the rest of the process.

The following process descriptions as regards Figs. 2 and 3 utilize feedback process control logic. A description of the typical instrumentation elements is provided here to help better understand how this logic process works.

A feedback control loop (for flow control) consists of three elements: (1) a sensor device to measure flow, (2) a control valve to vary to the flow, and (3) a flow controller to direct the control valve to open or close as necessary to maintain the desired flow.

Micro Motion coriolis mass flow meters have been utilized in past processes with demonstrated flow accuracy and are depicted in the following process descriptions. These

instruments are available from Micro Motion, Inc. USA, 7070 Winchester Circle, Boulder, CO 80301. These particular instruments use coriolis technology to provide a direct mass flow rate indication (as opposed to a volumetric flow indication which must be converted to mass units and be corrected for temperature variation) and also contain a flow signal transmitter used to provide a feedback flow signal to a control system computer. The size specification of the mass meter depends on the magnitude of the desired flow, density/viscosity characteristics of the flowing liquid, and pressure drop inherent with the associated piping.

Typical automatic control valves are pneumatically actuated to raise/lower a stem in the valve body. A precisely machined and specifically contoured "trim" is attached to the stem and internally resides in the flow path within the valve body. The trim serves to vary the size of the flow orifice as the stem moves up and down. The trim size is specified to provide a particular flow range for a given pressure drop across the valve. The pneumatic actuation signal is typically provided from an I/P device used to convert an electronic signal from a controller (usually measured in milliamps with a 4-20 mA range) to a corresponding pneumatic signal (usually measured in gauge pressure with a 3-15 psig range). Air pressure is supplied to the I/P device which in turn supplies a precise pressure to actuate the valve. The I/P device is usually calibrated at 0-100% scale of a 4-20 mA electronic signal to correspond to a 3-15 psig pneumatic signal at 0-100% scale of the desired flow range (i.e. 4 mA = 3 psig = 0 flow, 20 mA = 15 psig = 100% flow). Depiction of the I/P devices have been omitted in the proposed flow diagrams as they are universally assumed to be required. Size specification of the particular valve depends on the desired pressure drop across the valve, pipe size, and trim selection to provide the desired flow range. Control valves for 1/2 inch to 1 inch diameter process lines are typically available from Badger Meter, Inc. Industrial Division, 6116 East 15th St., Tulsa, OK 74158.

The controller is the heart of the control loop and is usually an electronic "black box" within the control system computer software. Most controllers are one of three types:

Proportional (P), Proportional Integral (PI), or Proportional Integral Derivative (PID). The names reflect what type of response action will be taken to adjust the control signal. In depth descriptions of each type will not be provided here. Most flow control loops use a PI controller due to the fast response nature of the flow measurement and control valve.

5           The overall feedback control loop functions as follows:

10           A desired flow value (setpoint) is input to the controller. A sensor device measures the current flow (measured variable) and returns the current flow value to the controller. The controller calculates the error between the measured variable and the desired setpoint value. The controller then supplies a signal to the I/P and control valve to vary the position (manipulated variable) of the control valve for either increased or reduced flow to minimize the error between the actual and desired flow values. The determination of how fast or how much to vary the position of the control valve depends on the tuning parameters supplied to the controller for Proportional Integral response. The control loop is "tuned" by changing these parameters to achieve optimal response (error minimization) to process upsets or setpoint changes.

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20           The processes of Figs. 2 and 3 utilize nested cascade ratio flow control to continuously produce the concentrated liquid biocidal compositions. Cascade ratio control is based on feedback control loops. For this type of control, a primary material stream is controlled at a desired flow setpoint. The flow transmitter that provides feedback response to the controller, usually called the master controller, also sends a flow signal to a ratio controller. This signal becomes the setpoint for a second material stream flow controller and hence the term cascade. This controller, usually called the slave controller, provides a signal to a control valve controlling the flow of a second material stream. A flow element in the second stream measures the flow and returns a signal back to the ratio flow controller. The secondary controller calculates the error between the measured flow value and the remotely supplied setpoint. The secondary controller then provides a signal to vary the second control valve accordingly to maintain the secondary flow as a ratio of the primary flow.

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The flow controllers are usually contained as individual block elements within the operating software of a process control computer system. A typical control system is a Foxboro I/A Distributed Control System (DCS).

Figure 2

Reference will now be made specifically to Fig. 2. This Figure describes a flow control system in which the alkali metal sulfamate formed is sodium sulfamate using sodium hydroxide as the base. However, the system is applicable to use of other alkali metal sulfamates formed using water-soluble bases other than sodium hydroxide. The control basis for the process of Fig. 2 is the nested cascade ratio flow control system employed to simultaneously control chlorine flow rate at a set ratio of a desired bromine flow rate. The combined total bromine/chlorine flow rate is then used to simultaneously control the sodium sulfamate flow rate at a desired ratio of the bromine/chlorine flow rate.

One of the vessels depicted is used to neutralize sulfamic acid to form sodium sulfamate. The desired water charge is added to such vessel. Solid sulfamic acid is charged from individual bags or supersacks to the same vessel with agitation to form an aqueous sulfamic acid slurry solution. An aqueous solution of 25% caustic (NaOH) is fed to the sulfamic acid solution to form aqueous sodium sulfamate. The sodium sulfamate solution is then transferred via pump pressure to the second depicted vessel which is equipped with a pump around circulation loop. A feed stream from the circulation loop is used to feed sodium sulfamate to the remaining continuous portion of the process.

Liquid bromine is fed continuously from a pressurized bromine supply vessel. The bromine (primary stream) flows through a Micro Motion mass flow meter then through an automatic control valve. The desired bromine flow rate is input as a setpoint to the bromine flow controller (master controller). The flow controller then sends a signal to the bromine control valve to vary the flow to maintain the desired flow rate. A one-way check valve is installed downstream of the bromine control valve to prevent back flow into the bromine supply line.



Liquid chlorine is supplied continuously from a bulk supply vessel either by tank vapor pressure or augmented with nitrogen pressure. Chlorine (secondary stream) flows through a Micro Motion mass flow meter then through an automatic control valve. The flow rate signal from the primary bromine mass flow meter/transmitter is sent to the chlorine ratio flow controller as a remote setpoint. The chlorine ratio flow controller then sends a signal to the chlorine control valve to vary the chlorine flow as a ratio of the bromine flow rate. A one-way check valve is installed downstream of the chlorine control valve to prevent back flow into the chlorine supply line.

The bromine and chlorine lines are brought together into a multi-element static mixer, commonly available from Koch Engineering Company, Inc., P.O. Box 8127, Wichita, KS 67208. The static mixer functions to provide dynamic in-line mixing with minimal linear space and no moving parts.

The flow rate signals from both the bromine and chlorine mass flow meters/transmitters are output to the computer control system and are summed together to obtain an overall flow rate of both streams. The overall flow rate value is then sent to a second ratio flow controller as a remote set point for the sodium sulfamate stream. The sodium sulfamate stream is supplied from pump pressure from the pump around circulation loop on the second depicted vessel. This stream flows through a Micro Motion mass flow meter then through an automatic control valve. The flow rate signal from the sodium sulfamate mass flow meter/transmitter is sent to the ratio controller which sends a signal to the control valve to vary the sodium sulfamate flow rate as a ratio of the combined bromine/chlorine flow rate. A one-way check valve is installed downstream of the sodium sulfamate control valve to prevent back flow into the sodium sulfamate supply line.

The sodium sulfamate stream and the combined bromine/chlorine stream exiting the first static mixer are brought together into a second multi-element static mixer. The exiting stream from this static mixer is the desired concentrated liquid biocidal composition, which is sent to a bulk product storage tank.

The advantage of the process flow system of Fig. 2 is that preparation of the sodium sulfamate solution can take place outside of the continuous portion of the process. The water, caustic, and sulfamic acid can be charged as normal batch operations with a large solution being prepared in advance and transferred to the sodium sulfamate feed vessel as required. Additionally the entire process can be controlled by entering a single set point for the desired bromine flow rate. All other material flow rates are obtained as internal remote setpoints. It should be noted that the magnitude of the desired flow ratios for the ratio controllers are typically configured within the individual controller as set parameters as opposed to user entered setpoint values.

### Figure 3

The process flows and control systems of Fig. 3 will now be considered. As is the case of Fig. 2, Fig. 3 is described with reference to a flow control system in which the alkali metal sulfamate is sodium sulfamate formed using sodium hydroxide as the base. However, the system is applicable to the use of any water-soluble alkali metal sulfamate formed using other water-soluble alkali metal bases.

The process of Fig. 3 eliminates the second vessel depicted in Fig. 2, the vessel that is used in Fig. 2 as a sodium sulfamate supply vessel. The overall system of Fig. 3 includes additional control elements for the single vessel of Fig. 3 to continuously neutralize sulfamic acid and to feed sodium sulfamate solution to the process. The continuous mixing process to feed bromine, chlorine, and sodium sulfamate remain as in Fig. 2.

In the process of Fig. 3, an aqueous solution of 25% caustic is fed to the reaction vessel depicted through a Micro Motion mass flow meter then through an automatic control valve. A desired caustic flow rate setpoint is entered into the caustic flow rate controller. The caustic flow controller then sends a signal to the control valve to suitably vary the caustic flow in order to maintain the desired flow rate. The flow rate signal from the caustic mass flow meter/transmitter is also sent as a remote setpoint to a water ratio flow controller.

Water is fed to the reaction vessel depicted through a Micro Motion mass flow meter then through an automatic control valve. The water ratio controller then sends a signal to the control valve to vary the water flow as a ratio of the caustic flow rate.

5 Solid sulfamic acid is charged to the depicted vessel at a flow rate consistent with the water/caustic flow to provide the necessary sulfamic acid/sodium sulfamate concentration within the vessel. A Rotolock valve is typically installed in the solids charge line to accomplish solids feeding at a set flow rate. This type of valve is a multi-vane rotary valve coupled to a direct current (DC) motor with a speed controller. The motor speed is adjusted to provide the desired solids feed rate (as determined from separate calibration for speed vs. flow rate). The Rotolock system can be further enhanced by instrumenting for automatic feedback control. This is usually accomplished by mounting the solids hopper feeding the Rotolock valve on weigh cells. For this setup, a desired solids feed rate is entered into a feed controller. The controller sends a signal to the motor to either speed up or slow down to achieve the desired flow rate. The solids flow rate is obtained by internal calculation of the loss-in-weight over time from the solids hopper. If the sulfamic acid charge system was instrumented for automatic control, the logical extension would be to send the solids flow rate signal to the caustic flow controller as a remote setpoint for the desired caustic flow. Since this step consists of a neutralization reaction, a certain amount of residence time is required for complete neutralization to sodium sulfamate. The available information indicates that the neutralization is mass transfer limited by the caustic feed rate and also by the cooling capacity of the reactor. This neutralization is somewhat exothermic and requires cooling to remove the generated heat. A pump around circulation loop is one way to provide sufficient residence time if the required sodium sulfamate flow rate for the rest of the process is not excessively large.

25 Bromine, chlorine, and sodium sulfamate are then fed identically as in the process of Fig. 2. Sodium sulfamate is fed continuously by taking a feed stream from the pump around circulation loop from the depicted reaction vessel and flowing through a mass flow

meter and control valve. The desired flow rate is obtained as a remote setpoint to a ratio flow controller from the summation of the total bromine/chlorine feed rate.

5 The advantage to the process of Fig. 3 is the elimination of one process vessel. This elimination is offset, at least to some extent, by the expense of additional control elements required for feeding water, caustic, and sulfamic acid.

10 It will now be understood and appreciated that the automatic flow control systems described herein can be effectively utilized in process layouts other than those depicted in Figs. 2 and 3. One example of one such other process layouts is described with reference to Fig. 1.

15 Even though the claims hereinafter may refer to substances, components and/or ingredients in the present tense ("comprises", "is", *etc.*), the reference is to the substance, component or ingredient as it existed at the time just before it was first contacted, blended or mixed with one or more other substances, components and/or ingredients, or if formed in solution, as it would exist if not formed in solution, all in accordance with the present disclosure. It matters not that a substance, component or ingredient may have lost its original identity through a chemical reaction or transformation during the course of such contacting, blending, mixing, or *in situ* formation, if conducted in accordance with this disclosure.

20 Each and every patent or publication referred to in any portion of this specification is incorporated *in toto* into this disclosure by reference, as if fully set forth herein.

25 This invention is susceptible to considerable variation in its practice. Therefore the foregoing description is not intended to limit, and should not be construed as limiting, the invention to the particular exemplifications presented hereinabove. Rather, what is intended to be covered is as set forth in the ensuing claims and the equivalents thereof permitted as a matter of law.